Preprint
UCRL-JC-144144

High Reflectivity of Silver Extended Down to 200 NM

N. Thomas, J. Wolfe

This article was submitted to
Optical Society of America's Eighth Topical Meeting on Optical Interference Coatings, Alberta, Canada, July 15-20, 2001

June 4, 2001

U.S. Department of Energy

Lawrence
Livermore
National
Laboratory

This work was performed under the auspices of the United States Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

High Reflectivity of Silver Extended Down to 200 NM

Norman Thomas and Jesse Wolfe
Lawrence Livermore National Laboratory
University of California, Livermore, CA 94550

Abstract

Silver has the highest reflectance of all of the metals, but it tarnishes in the presence of sulfides, chlorides, and oxides in the atmosphere. Also, the silver reflectance is very low at wavelengths below 400 nm making aluminum more desirable mirror coating for the UV region. We have found a way to prevent silver tarnishing by sandwiching the silver layer between two thin layers of $NiCrN_x$, and to extend the metal's high reflectance down to 200 nm by depositing the (thin) Ag layer on top of Al. Thus, the uv is transmitted through the thin Ag layer below 400 nm wavelength, and is reflected from the Al layer underneath. This UV-shifted durable coating[1] provides a valuable alternative to the aluminum coating for telescope mirror coatings where collection efficiency is an important consideration.

Introduction

Evaporated silver on mirror substrates has several advantages compared to other metals. It has the highest reflectivity from 400 nm through the infrared and the lowest polarization splitting compared to any other metal. Figure 1 compares the reflectance for silver, aluminum and gold. The disadvantage of bare silver is that it tarnishes under ordinary atmospheric conditions and does not have a high reflectance below 400 nm. There is a minimum reflectance at 320 nm due to a surface plasmon resonance. Aluminum, on the other hand, has a dip in reflectance at 850 nm due to inter-band transitions, but reflects well down to 280 nm, the cutoff for atmospheric transmission. If a thin layer of silver is deposited on aluminum, the advantages of silver and aluminum are combined: silver reflects for $\lambda > 400$ nm and masks the dip at 850 nm, and aluminum reflects for $\lambda < 400$ nm where silver is semi-transparent.

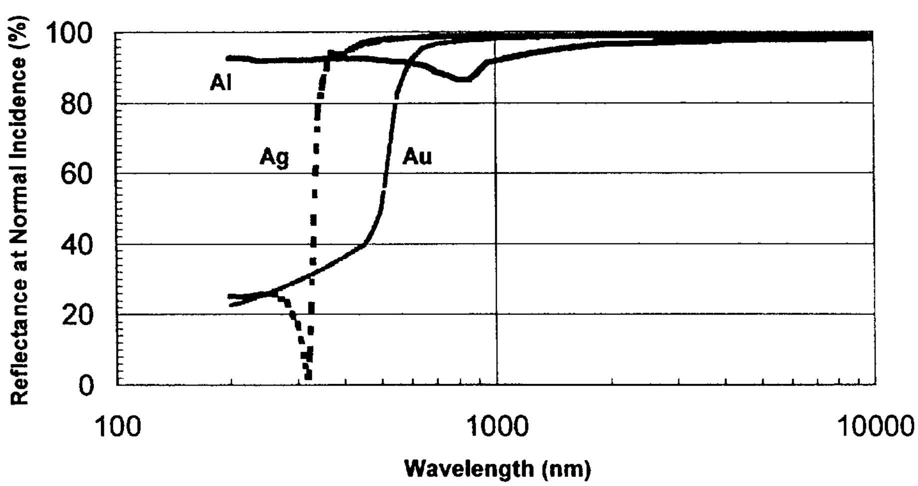

Fig. 1 Reflectance of evaporated metals in the visible and infrared

Silver is a noble metal which is completely stable in aqueous solutions of any pH as long as oxidizing agents or complexing substances are not present. In the presence of such substances, the high specular reflectivity of silver is degraded by sulfidation, chloridation and oxidation with corrosive chemicals in the atmosphere such as H_2S, O, $O^{=}$, H_2O_2, SO_2, CL^{-}, etc. The corrosion products of silver are Ag_2S, AgCl, Ag_2O, Ag_2SO_4 and Ag_2CO_3 in increasing order of solubility. Since these products form in the thin water layer which is typically present on silver, the most likely precipitate is Ag_2S. Sandwiching the silver layer between two thin layers of $NiCrN_x$ was shown to stop these corrodants from lowering silver reflectance.

Thin Film Design

The basic coating design is shown in Figure 2. The materials for the enhancement layers are listed for three different coating designs: Phase I, II, and III. The Phase I design extends the high reflectance of silver down to 300 nm; Phase II shifts it down to 250 nm; and Phase III shifts down to 200 nm. The Phase III design meets the needs for many astronomical applications.

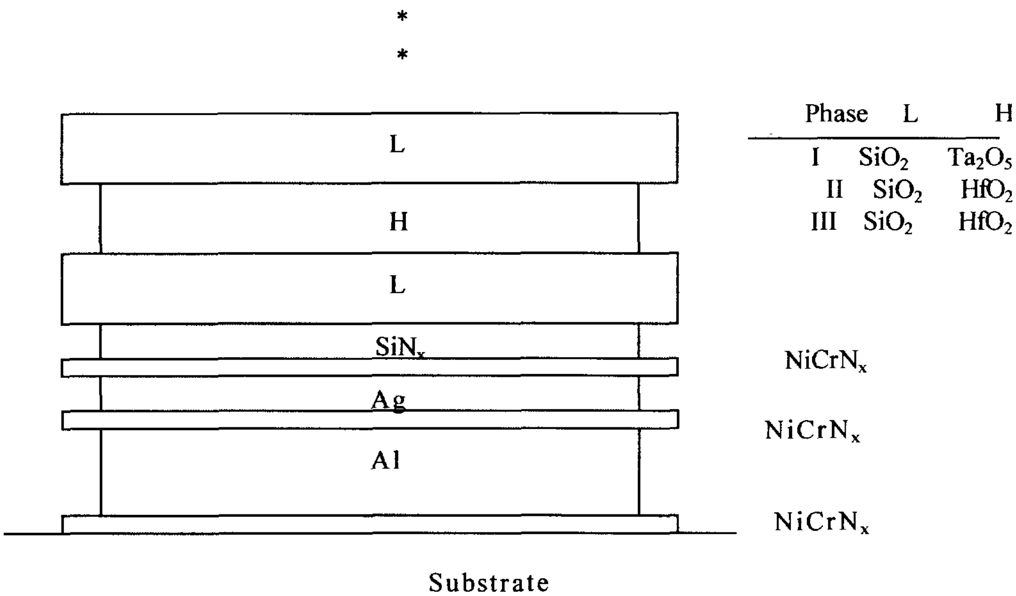

Fig. 2 Coating Design

The adhesion layer provides nucleation sites on the substrate for the sputtered silver , and works in combination with the $NiCrN_x$ layer to improve mechanical and chemical durability. The $NiCrN_x$ layer alloys with the silver and helps in preventing sulfides, chlorides and oxides from reacting with the silver. The silicon nitride layer (~30 Angstroms physical thickness) improves mechanical durability and acts as a barrier layer preventing corrodants from reacting with the silver. The metal oxide layers are combinations of silica, tantala or hafnia and serve to increase the uv reflectance.

The essence of the uv-shifted durable silver coating is the thin silver layer (~300-500 Angstroms physical thickness) on top of an aluminum layer and the encapsulation of the silver layer between two thin layers of nickel chrome nitride (8-10 Angstroms physical thickness). Below about 380 nm, incident light is transmitted through the silver layer and reflected by the aluminum layer. Figure 3 compares the theoretical reflectivity for Phase I, II and III to bare Ag.

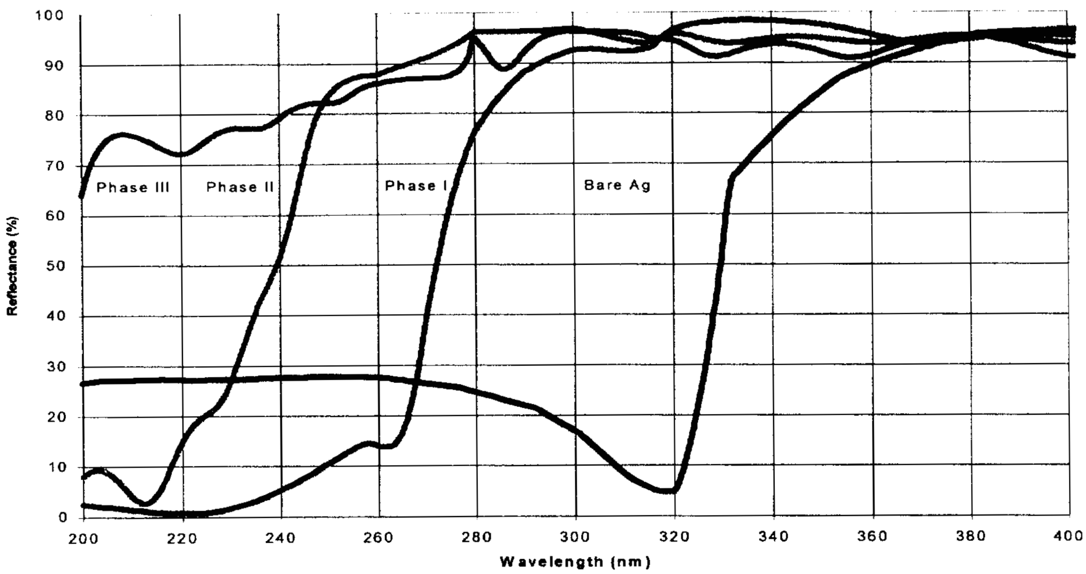

Fig. 3 Theoretical reflectance of Phase I, II, and III coating designs compared to bare silver.

Result and Conclusions

Phase I design was successfully coated on a 22-inch diameter collimator mirror from the HRIS instrument package on the Keck Telescope. This durable silver coating had an average reflectance of > 94% from 280nm to > 2500 nm which is shown in Figure 4. The deposition geometry for this coating is described by Jesse Wolfe in another paper at this conference. Earlier, Phase III was successfully coated for an evaluation study for Hubble Space Telescope. Both coatings passed Mil-Spec 13508.

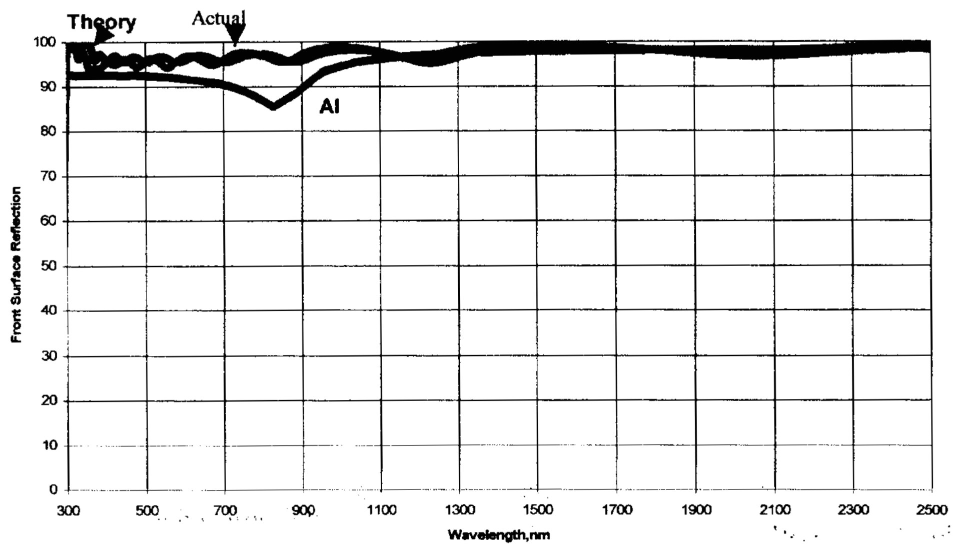

Fig. 4 Actual and theoretical reflectance for Keck mirror compared to aluminum.

1. "UV-Shifted Durable Silver Coating for Astronomical Mirrors", Norman Thomas and Jesse Wolfe, SPIE 4003-49, Munich, Germany, March, 2000.